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Evaluation of bucked shin in a horse leg using ultrasonic technique.

Taisei Tsubata[1 ‡], Shouta Kitajima[1], Shuta Kodama[1], Norihisa Tamura[2], Hiroshi Mita[2], Ko Chiba[2] and Mami Matsukawa[1*]
([1]Doshisha Univ.; [2]Nagasaki Univ.; [3]JRA Equine Research Institute.)

1. Introduction

Racehorses such as thoroughbreds have thin limbs. Hard training in the growth period causes bucked shin. Bucked shin is a tiny stress fracture that forms a new layer of bone and can develop into a life-threatening fracture. Therefore, early detection and prevention of bucked shin in racehorses are very important.

The present main diagnostic technique in the breeding field is palpation. Subsequently, the X ray computed tomography (CT) has been used as necessary. However, CT has problems of radiation exposure and require expensive systems, which are difficult to use in the field. Therefore, a safe, inexpensive, and easy technique for bone evaluation in the field must be developed. One of the promising candidates is quantitative ultrasound (QUS)[1)]. QUS is inexpensive, safe, and portable and can measure bone strength related to the elastic properties.

In this study, the Finite Difference Time Domain (FDTD) method was used to simulate wave propagation in a digital model of a horse leg with bucked shin[2)]. An ultrasonic evaluation technique for bucked shin was investigated using a simple system.

2. Construction of a bone digital model

A digital equine bone model was created using the high-resolution peripheral quantitative computed tomography (HR-pQCT; Xtreme CT II, SCANCO Medical AG, Brüttisellen, Switzerland) images of a third metatarsal bone with a mild bucked shin. A cross-sectional view of the bone model is shown in Fig. 1 (a). The voxel size of the model was 61 µm. The model was heterogeneous. The bone mass densities in the model were set in the range from 1300 to 2760 kg/m^3 [3)]. The wave velocities in the axial direction were measured by an ultrasonic pulse technique in the MHz range. In the model, they were in the range of 3850–4150 m/s. The wave velocities in the radial direction were in the range of 3250-3530 m/s. The elastic constants were estimated from the density and velocity. Using an interpolation technique and Poisson's ratio of 0.33, we estimated all constants in all voxels following studies of Nakatsuji, Yamato and Hata [4-6)].

E-mail: [‡]ctwh0370@mail4.doshisha.ac.jp
[*]mmatsuka@mail.doshisha.ac.jp

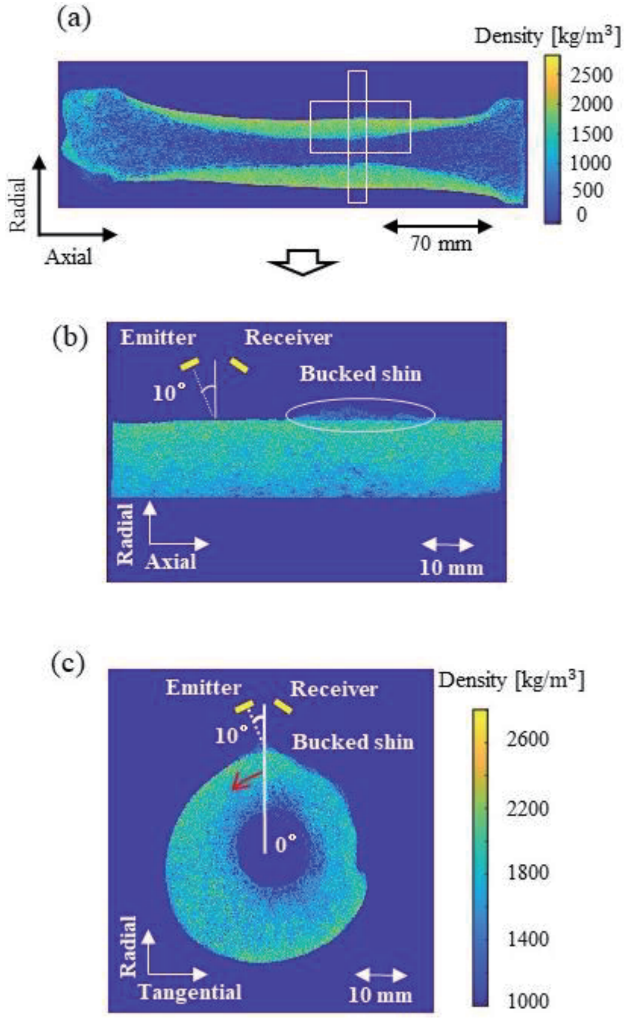

Fig. 1 A 2D digital equine bone model (mass density). (a) Density distribution of the bone. Simulation conditions in (b) the axial-radial cross-section, and (c) the tangential-radial cross-section.

3. Simulation of wave propagation in the model

The simulation conditions in the axial and tangential directions for the elastic FDTD method are shown in Figs. 1(b) and (c). In these simulations, attenuations were not considered. The Higdon's second order absorbing boundary condition was used[7)]. Considering Courant's stability conditions[8)], the temporal resolution was 7.0 ns. A water (2.25 GPa, 1000 kg/m3) layer was set around the bone model instead of soft tissue. The input signal to the emitter was one cycle of sinusoidal wave at 1 MHz with Hann window. For the simulation of the model in Fig. 1 (b), the transmitter and receiver were placed 5 mm from the bone surface at a tilt angle of 10°. Figure 1 (c) shows the simulation condition in the tangential – radial cross section. The transmitter and receiver were fixed, and the bone sample was rotated to transmit ultrasound waves with angles from -25° to 25°. Here, the part with bucked shin area was set as 0°.

4. Results and discussion

A waveform obtained from the simulation is shown in Fig. 2 (a). In order to check effects of the surface at the bucked shin, relationship between transducer position and the initial peak amplitude of wave was checked (Fig. 2 (b)). The relationship between the rotational angle of the bone sample and the initial peak amplitude of wave is also shown in Fig. 3. The amplitudes were relatively large in the normal area, whereas they were small in the bucked shin area. One reason for the results is bone properties in the bucked shin area. The BMDs in the bucked shin area were about 70 % of the normal area and longitudinal wave velocities were lower. In addition, scattering of sound waves due to the surface irregularities in the bucked shin area might cause the small amplitudes. These results indicate that the simple ultrasonic system can detect the initial backed shin with irregularity (height around 1 mm) in the horse leg. Although palpation of initial diagnosis by special technicians is still the mainstream in the breeding sites, possibility of quantitative bucked shin detection by a simple ultrasonic method was confirmed.

5. Conclusions

Using the FDTD method, a simple ultrasonic technique was applied to detect the initial bucked shin in the equine metatarsals. Evaluating changes in amplitude of the reflected wave from the bone surface, we could detect small surface irregularities due to the buked shin. The simple reflection method used in this study can be performed by a portable and inexpensive equipment and has a high potential for quantitative evaluation of leg bones in livestock breeding.

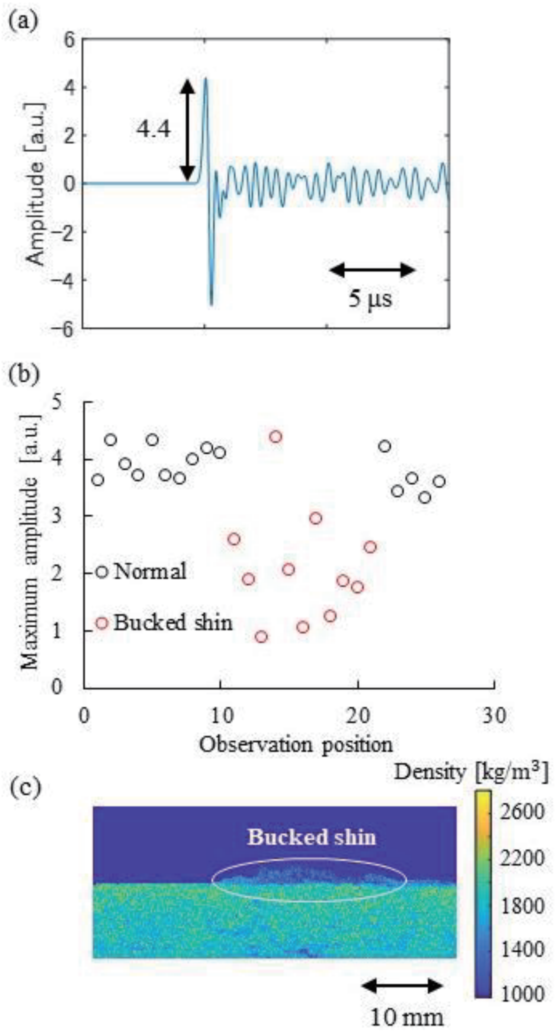

Fig. 2 Simulation results in the axial-radial cross-section. (a) Observed waveform, (b) position vs. maximum amplitude, (c) the surface shape.

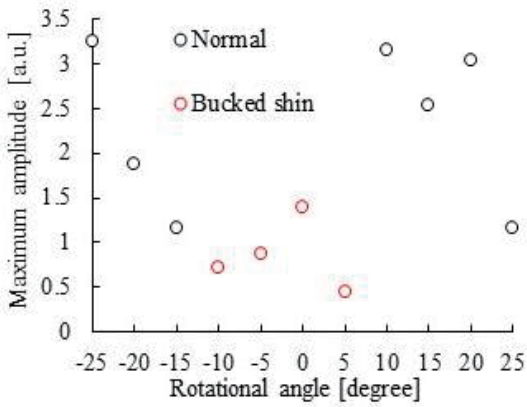

Fig. 3 Simulation results in the axial-radial cross section. (Rotation angle vs. maximum amplitude)

References

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